

**SYNTHESIZE AND CHARACTERIZATION OF
Al₂O₃-, BaTiO₃-, TiO₂-, CuO-CCTO COMPOSITES
FOR WIDEBAND DIELECTRIC RESONATOR
APPLICATION**

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**SYNTHESIZE AND CHARACTERIZATION OF Al_2O_3 -, BaTiO_3 -, TiO_2 -,
 CuO -CCTO COMPOSITES FOR WIDEBAND DIELECTRIC RESONATOR
APPLICATION**

by

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**Thesis submitted in fulfilment of the
requirements for the degree of
Doctor of Philosophy**

Mac 2018

DECLARATION

I hereby declare that I am the sole author of this dissertation. This is a true copy of the dissertation, including any required final revisions, as accepted by my examiners. It has not previously submitted for the basis of the award of any degree or diploma or other similar title of this for any other diploma/examining body or university. I understand that my dissertation maybe made electronically available to the public.

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LIST OF ABBREVIATION

BW%	Percentage of bandwidth
DRA	Dielectric resonance antenna
EDX	Energy Dispersive X-ray
RL	Return loss
FESEM	Field Emission Scanning Electron Microscopy
XRD	X-ray Diffraction

LIST OF SYMBOLS

%	Percentage
°	Degree
°C	Degree Celsius
°C/min	Degree Celsius per minutes
MPa	Megapascal
λ	Wavelength
ϵ_r	Dielectric constant
$\tan \delta$	Tangent loss

**SINTESIS DAN PENCIRIAN KOMPOSIT Al_2O_3 -, BaTiO_3 -, TiO_2 -,
 CuO -CCTO UNTUK KEGUNAAN PENYALUN DIELEKTRIK JALUR
LEBAR**

ABSTRAK

Antena logam telah digunakan secara meluas dalam sistem komunikasi tanpa wayar sejak beberapa tahun yang lalu. Secara umum saiz antena yang digunakan adalah besar disamping kehilangan haba ($\tan \delta$) yang tinggi dan jalur lebar yang kecil. Kelemahan ini boleh diselesaikan dengan menggunakan bahan seramik dengan pemalar dielektrik (ϵ_r) yang tinggi dan kehilangan haba yang rendah seperti $\text{CaCu}_3\text{Ti}_4\text{O}_{12}$ (CCTO) yang juga dikenali sebagai antena penyalun elektrik (DRA). Pada frekuensi 8 GHz, didapati bahawa ϵ_r CCTO ialah 62.76 dan $\tan \delta$ adalah 0.1458. Ia menghasilkan isyarat antara 8.56-9.12 GHz dengan 6.60% jalur lebar. Tetapi $\tan \delta$ bagi CCTO adalah tinggi iaitu lebih daripada 0.1 dan liputan jalur lebar kurang daripada 10% dimana ia tidak mampu meliputi bahagian yang lebih luas dalam sistem komunikasi jalur X (8 GHz hingga 12 GHz). Oleh itu, untuk meningkatkan potensi CCTO sebagai DRA yang lebih baik, bahan oksida yang lain perlu ditambah. Dalam kajian ini, Al_2O_3 , BaTiO_3 , TiO_2 and CuO telah ditambah daripada 20, 40, 50, 60, dan 80 wt% kepada CCTO. Didapati bahawa ϵ_r bagi penambahan Al_2O_3 kepada CCTO ialah 37.33 dan $\tan \delta$ dalam siri komposit ini ditambah baik ke nilai yang lebih rendah iaitu 0.0520. Komposit ini menghasilkan isyarat antara 8.67-9.26 GHz dengan lebar jalur 5.61% (penambahan 20 wt% Al_2O_3). Penambahan BaTiO_3 telah meningkatkan ϵ_r kepada 85.23 dan $\tan \delta$ dalam siri ini antara 0.0627-0.0258. Hasil kajian menunjukkan komposit ini menghasilkan isyarat antara 9.33-10.21 GHz dengan 8.91% jalur lebar.

Penambahan 50 wt% TiO_2 menunjukkan ϵ_r berubah kepada 56.47 dan $\tan \delta$ dalam siri tersebut antara 0.0165-0.1108. Apabila di uji sebagai antena ia menyalun antara 10.03-11.36 GHz dengan 12.48% jalur lebar. ϵ_r yang tinggi iaitu 67.52 diperolehi daripada dengan penambahan 50wt% CuO dan $\tan \delta$ antara 0.0203-0.0878 serta menghasilkan isyarat pada julat 9.12-11.29 GHz dengan 21.26% jalur lebar. Semua keputusan ini menunjukkan bahawa semua sampel yang diuji boleh digunakan sebagai antena tetapi siri 50CCTO/50CuO menunjukkan prestasi yang terbaik berbanding dengan siri lain. Atas sebab itu, siri komposit ini seterusnya dioptimumkan dan didapati bahawa siri komposit (50CCTO/50CuO) ini menghasilkan ϵ_r yang tinggi iaitu 67.52 dan $\tan \delta$ yang rendah (0.0141). Siri komposit ini boleh meliputi julat frekuensi yang lebih luas dalam jalur X dan ia sesuai untuk dijadikan DRA dalam saiz yang lebih kecil dengan prestasi yang lebih baik.

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 CuO –CCTO COMPOSITES FOR WIDEBAND DIELECTRIC RESONATOR
APPLICATION**

ABSTRACT

Metallic antennas have been widely used in wireless communication system. In general this antenna is big in size with high tangent loss ($\tan \delta$) and the bandwidth is narrow with low efficiency. These shortcomings can be solved by using ceramic materials with high dielectric constant (ϵ_r) and low $\tan \delta$ such as $\text{CaCu}_3\text{Ti}_4\text{O}_{12}$ (CCTO), known as dielectric resonator antenna (DRA). At 8 GHz, ϵ_r is 62.76 and $\tan \delta$ is 0.1458 and resonated between 8.56 to 9.12 GHz with 6.6% bandwidth. However, its $\tan \delta$ is still considered as on the higher side (>0.1) and bandwidth coverage is less than 10% which is not able to cover a wider portion of the X band (8 GHz to 12 GHz) communication system. Therefore, to enhance the properties of DRA, CCTO properties can be modified through the addition with other oxides. In this research, Al_2O_3 , BaTiO_3 , TiO_2 and CuO , respectively, was added from 20, 40, 50, 60, and 80 wt% into CCTO. It was found that addition of Al_2O_3 has reduced ϵ_r to 37.33 but has improved $\tan \delta$ value to the lowest value of 0.0520. This antenna resonated between 8.67 to 9.26 GHz with 5.61% bandwidth (addition 20 wt% Al_2O_3). The addition of BaTiO_3 has increased ϵ_r to 85.23 with addition 80 wt% and $\tan \delta$ in these series between 0.0627 – 0.0258. The result shows these composites resonated between 9.33 to 10.21 GHz with 8.91% bandwidth. The addition of 50 wt% of TiO_2 shows ϵ_r of 56.47 and $\tan \delta$ of these composites between 0.0165-0.1108, resonated from 10.03 to 11.36 GHz with 12.48% bandwidth. The highest ϵ_r (67.52) was obtained from 50 wt%